

## CLAIMS

1. A method of dental registration, comprising:
  - 5 rigidly coupling a base element to a maxillofacial area;
  - inserting an object comprising at least one of a tool and a tool guide into a mouth in said maxillofacial area; and
  - determining a position of said object relative to said rigid element without a reference element outside of said mouth.
- 10 2. A method according to claim 1, wherein said base element comprises a rigid element.
3. A method according to claim 1, comprising acquiring a 3D radiological image of at least a part of said maxillofacial area.
- 15 4. A method according to claim 3, comprising acquiring a non-volumetric image of at least a part of said dental area including at least a part of said base element.
5. A method according to claim 4, comprising:
  - 20 identifying at least one registration mark of said rigid element on said non-volumetric image; and
  - registering said image to said 3D image, thereby registering said registration mark to said area.
- 25 6. A method according to claim 1, comprising:
  - acquiring a first image of at least a part of said maxillofacial area;
  - acquiring a non-volumetric image of least a part of said dental area including at least a part of said base element;
  - identifying at least one registration mark of said rigid element on said non-volumetric image; and
  - registering said image to said first image, thereby registering said registration mark to said area.

7. A method according to claim 6, wherein said first image comprises a surface image obtained using a plurality of measurable pins which penetrate gum tissue to bone tissue.
8. A method according to claim 6, wherein said non-volumetric image comprises a 2D transmission image.
9. A method according to claim 5, wherein determining comprises setting a desired position, and comprising selecting a desired relative position.
10. 10. A method according to claim 5, wherein determining comprises measuring an existing position.
11. A method according to claim 10, wherein determining comprises adjusting said object to a new position responsive to said measured position.
15. 12. A method according to claim 5, wherein determining comprises aiming said tool using said position, at said maxillofacial area.
13. A method according to claim 5, wherein rigidly coupling comprises inserting at least one pin into gum tissue of said maxillofacial area.
20. 14. A method according to claim 5, wherein rigidly coupling comprises coupling using a clamp.
25. 15. A method according to claim 5, wherein rigidly coupling comprises releasing said base element to elastically engage said maxillofacial area.
16. A method according to claim 5, wherein rigidly coupling comprises attaching using at least one screw.
30. 17. A method according to claim 5, wherein rigidly coupling comprises attaching to a single portion of said maxillofacial area.

18. A method according to claim 5, wherein rigidly coupling comprises attaching said rigid element to be adjacent to at least 35% of a jawbone of said maxillofacial area.
19. A method according to claim 5, wherein rigidly coupling comprises mounting on an  
5 unpeeled gum.
20. A method according to claim 5, wherein rigidly coupling comprises mounting on a tooth.
- 10 21. A method according to claim 5, wherein said base element is customized for a particular maxillofacial area.
22. A method according to claim 5, wherein said base element is mass produced.
- 15 23. A method according to claim 5, wherein acquiring a non-volumetric image comprises acquiring one or more 2D transmission X-ray image of at least part of said maxillofacial area.
24. A method according to claim 23, comprising viewing at least one opaque portion of said base element to determine an allowed drilling depth in said maxillofacial area.  
20
25. A method according to claim 5, wherein acquiring a non-volumetric image comprises optically scanning a surface of at least part of said maxillofacial area.
26. A method according to claim 5, wherein acquiring a non-volumetric image comprises  
25 reconstructing a surface geometry of at least part of said maxillofacial area.
27. A method according to claim 5, wherein acquiring a non-volumetric image comprises optically imaging at least part of said maxillofacial area.
- 30 28. A method according to claim 5, wherein acquiring a non-volumetric image comprises ultrasonically imaging at least part of said maxillofacial area.

29. A method according to claim 5, wherein acquiring a non-volumetric image comprises contact measurement using a plurality of measured pins that penetrate gum tissue.

30. A method according to claim 12, wherein aiming comprises adjusting one or more 5 joints on said tool to achieve said aiming.

31. A method according to claim 12, wherein said aiming comprises aiming at least 2 degrees of freedom of movement and orientation.

10 32. A method according to claim 12, wherein said aiming comprises aiming at least 3 degrees of freedom of movement and orientation.

33. A method according to claim 12, wherein said aiming comprises aiming at least 5 degrees of freedom of movement and orientation.

15

34. A method according to claim 12, wherein said aiming comprises adjusting a depth of penetration of said tool.

20 35. A method according to claim 12, wherein said aiming comprises planning a position and orientation of a tool path of said tool and adjusting at least one of said position and orientation according to said determining position.

36. A method according to claim 12, comprising monitoring at least one of a position and orientation of said tool during said aiming.

25

37. A method according to claim 36, wherein said monitoring comprises displaying.

38. A method according to claim 37, wherein said displaying comprises displaying an expected result of using said tool.

30

39. A method according to claim 37, wherein said displaying comprises displaying a current effect of said tool.

40. A method according to claim 37, wherein said displaying comprises displaying on a radiological image.
41. A method according to claim 37, wherein said displaying comprises updating said display at least once per minute.
42. A method according to claim 37, wherein said displaying comprises updating said display at least once per second.
- 10 43. A method according to claim 37, wherein said displaying comprises calculating an expected layout of a dental prosthesis on a bore formed using said tool; and displaying said expected layout with said monitored position.
- 15 44. A method according to claim 37, wherein said displaying comprises displaying a plurality of planned bores at different locations simultaneously.
45. A method according to claim 5, comprising calculating an expected layout of a dental prosthesis on a bore formed using said tool; and displaying said expected layout with said determined position.
- 20 46. A method according to claim 5, wherein said object is already mounted on said base element during said rigidly coupling.
- 25 47. A method according to claim 5, comprising rigidly attaching said object on said base element after said inserting.
48. A method according to claim 47, wherein attaching comprises attaching to a predetermining place on said base element.
- 30 49. A method according to claim 47, wherein attaching comprises attaching using an adhesive.
50. A method according to claim 47, wherein attaching comprises attaching mechanically.

51. A method according to claim 5, wherein said object comprises a dental soft tissue remover.

5 52. A method according to claim 5, wherein said object comprises a needle.

53. A method according to claim 5, wherein said object comprises a cutter.

54. A method according to claim 5, wherein said object comprises a laser.

10

55. A method according to claim 5, wherein determining a position comprises using a plurality of encoders embedded in said tool guide

15

56. A method according to claim 5, wherein determining a position comprises using a plurality of encoders embedded in said base.

57. A method according to claim 56, wherein said tool guide comprises a drill guide and comprising adjusting said drill guide to have a desired position and orientation.

20

58. A method according to claim 57, comprising attaching said adjusted drill guide to a dental area.

59. A method according to claim 57, comprising locking said adjusted drill guide to maintain its adjustment.

25

60. A method according to claim 12, wherein said tool comprises a drill and comprising measuring a length of a drill burr of said drill.

30

61. A method according to claim 5, wherein inserting an object comprises fabricating said object.

62. A method according to claim 61, wherein fabricating comprises drilling a bore in said object.

63. A dental tool guide base, comprising:

a structure adapted to be rigidly and removably attached to a gum-covered jaw;

at least one guide attachment point defined on said structure, which at least one guide

5 attachment point is adapted to rigidly attach a tool guide section to said structure; and

at least one registration mark adapted to be identified relative to said structure.

64. A base according to claim 63, wherein said structure is elastically distortable for said attaching.

10

65. A base according to claim 63, wherein said structure comprises at least one attachment pin adapted for attaching to a gum covered jaw.

66. A base according to claim 63, wherein said structure comprises at least one attachment

15 screw adapted for attaching to a gum covered jaw.

67. A base according to claim 63, wherein said structure is in the form of a stent.

68. A base according to claim 63, wherein said structure is adapted to be attached to a  
20 small locality of said jaw.

69. A base according to claim 63, wherein said structure is mass-produced.

70. A base according to claim 63, wherein said registration mark is suitable for  
25 identification by optical surface scanning method.

71. A base according to claim 63, wherein said registration mark is suitable for identification by an optical imaging method.

30 72. A base according to claim 63, wherein said registration mark is suitable for identification by two-dimensional x-ray images.

73. A base according to claim 63, wherein said registration mark is suitable for identification by ultra-sound imaging.

5 74. A base according to claim 63, wherein said attachment point is a snap-locking attachment point.

75. A base according to claim 63, wherein said registration mark and said guide attachment points are spatially separated.

10 76. A base according to claim 63, wherein said registration mark and said guide attachment points are spatially overlapping.

77. A base according to claim 63, wherein said structure comprises two opposing panels connected by at least one bridge element.

15 78. A base according to claim 77, wherein said structure comprises two opposing panels connected by at least one bridge element.

20 79. A base according to claim 78, wherein said bridge includes an aperture for guiding a drill bore therethrough.

80. A base according to claim 63, wherein said guide attachment point is positioned to a side of said jaw when said structure is attached to a gum-covered jaw.

25 81. A base according to claim 63, wherein said structure is adapted to be attached to at least one tooth.

82. A base according to claim 63, wherein said structure is adapted to mount on a gum.

30 83. A base according to claim 63, wherein said structure is substantially transparent to x-rays, except for said registration mark.

84. A base according to claim 77, comprising a radio-opaque grid on at least one of said panels.

85. A base according to claim 77, comprising:

5 a plurality of pins in at least one of said panels, said pins being adapted to pierce gum tissue but not bone; and at least one encoder which reads a position of at least one of said pins.

86. A base according to claim 63, wherein said guide attachment point is adapted to hold a block of material.

10

87. A base according to claim 63, comprising a solid block adapted for engagement by said guide attachment point.

88. A dental tool guide, comprising:

15

(a) a base section adapted to be mechanically coupled to hard tissue;

(b) an adjustable guide section having a range of possible orientations in a vicinity of said base section; and

(c) at least one encoder adapted to fit in a human mouth and configured to electronically report an orientation of said guide section relative to said base section.

20

89. A tool guide according to claim 88, wherein said guide section is mechanically coupled to said base section.

25

90. A tool guide according to claim 88, wherein said guide section is mechanically decoupled from said base section.

91. A guide according to claim 88, comprising circuitry which presents at least an indication of said orientation.

30

92. A guide according to claim 88, comprising circuitry which transmits said report in a wireless manner.

93. A guide according to claim 88, comprising circuitry which transmits said report in a wired manner.

94. A guide according to claim 88, wherein said base is in the form of a surgical stent.

5

95. A guide according to claim 88, wherein said base is in the form of a brace extending out of said mouth.

96. A guide according to claim 88, wherein said guide section comprises at least one  
10 adjustable portion.

97. A guide according to claim 96, wherein said adjustable portion is adapted to be locked.

98. A guide according to claim 97, wherein said locking comprises mechanical locking.

15

99. A guide according to claim 97, wherein said locking comprises locking by application of heat.

100. A guide according to claim 88, wherein said guide is opaque to x-ray radiation.

20

101. A guide according to claim 88, wherein said guide is transparent to x-ray radiation.

102. A guide according to claim 88, wherein said guide comprises at least one radio-opaque marking.

25

103. A guide according to claim 88, wherein said encoder comprises an optical encoder.

104. A guide according to claim 88, wherein at least one of said at least one encoder is mounted on said base.

30

105. A guide according to claim 88, wherein at least one of said at least one encoder is mounted on said guide.

106. A guide according to claim 88, wherein at least one of said at least one encoder comprises at least two sensing parts, a sensed part and a sensing part, each one of said parts mounted on a different one of said guide and said base.

5 107. A guide according to claim 88, wherein said base is customized to patient's jaw or teeth

108. A guide according to claim 88, wherein said base includes a registration mark.

10 109. A guide according to claim 88, wherein said guide section is in the form of an arm.

110. A guide according to claim 109, wherein said arm has at least 3 degrees of freedom relative to said base.

15 111. A guide according to claim 109, wherein said guide section comprises:  
a plurality of joints which adjust said drill guide section relative to said base; and  
a plurality of encoders which directly measure orientation of said joints.

112. A guide according to claim 111, wherein said joints are orthogonal to each other.

20 113. A guide according to claim 88, comprising a drilling depth adjuster.

114. A dental tool guide aiming-device, comprising:  
a base adapted to fixedly engage an adjustable tool guide;  
25 a guide holder adapted to engage a guiding section of said tool guide;  
at least one control adapted to move said guide holder and thereby change the orientations of one or more joints of said drill guide.

115. An aiming device according to claim 114, wherein said guide holder comprises a peg.

30 116. An aiming device according to claim 114, wherein said guide holder prevents translation of said guide.

117. An aiming device according to claim 114, wherein said control comprises a manual control.

118. An aiming device according to claim 114, wherein said control comprises a motor.

5

119. An aiming device according to claim 114, comprising a controlling attachment to a computer.

120. An aiming device according to claim 119, wherein said computer includes a display  
10 adapted to display an effect of said adjustment.

121. A aiming device according to claim 114, comprising a drill depth adjuster.

122. An aiming device according to claim 121, comprising a set of replaceable depth  
15 adjusters for different depths.

123. An aiming device according to claim 114, comprising a set of sleeves for varying an outer diameter of said peg.

20 124. An aiming device according to claim 114, comprising a drill length measuring element.

125. A dental tool guide, comprising:

(a) a base section adapted to be mechanically coupled to hard tissue;  
25 (b) an adjustable guide section having a range of possible orientations in a vicinity of said base section; and  
(c) a lock which selectively mechanically locks said guide section to prevent further adjustment.

126. A guide according to claim 125, wherein said base is in the form of a surgical stent.

30

127. A guide according to claim 125, wherein said base is in the form of a brace extending out of said mouth.

128. A guide according to claim 125, wherein said guide section comprises at least one adjustable portion.

129. A guide according to claim 125, wherein said locking comprises mechanical locking.

5

130. A guide according to claim 129, wherein said locking comprises tightening of a screw.

131. A guide according to claim 125, wherein said locking comprises locking by application of heat.

10

132. A guide according to claim 125, wherein said guide is opaque to x-ray radiation.

133. A guide according to claim 125, wherein said guide is transparent to x-ray radiation.

15

134. A guide according to claim 125, wherein said guide comprises at least one radio-opaque marking.

135. A guide according to claim 125, wherein said base is customized to a patient's jaw or teeth.

20

136. A guide according to claim 125, wherein said base includes a registration mark.

137. A guide according to claim 125, wherein said guide section is in the form of an arm.

25

138. A guide according to claim 137, wherein said arm has at least 3 degrees of freedom relative to said base.

139. A guide according to claim 137, wherein said guide section comprises a plurality of joints which adjust said drill guide section relative to said base.

30

140. A guide according to claim 139, wherein said joints are orthogonal to each other.

141. A guide according to claim 125, comprising a drilling depth adjuster.

142. A guide according to claim 125, wherein said guide section is permanently attached to said base.

5 143. A guide according to claim 125, wherein said guide section is selectively attachable to said base.